



Risk assessment through landslide susceptibility map

Chiara Calligaris*, Giorgio Poretti*, Shahina Tariq** and Hawas Khan***

*University of Trieste, D.M.G. (Italy)

**COMSATS, Islamabad (Pakistan)

***KIU, Gilgit (Pakistan)

Islamabad, 9-10 th September 2013









INTRODUCTION

The aim of the project is the identification of the landslide-prone areas inside the borders of the Central Karakorum National Park (CKNP) in order to a have a first landslide inventory in the area.

A qualitative risk assessment is possible where a detailed landslide inventory map and a map of structures (houses, buildings, etc.) and infrastructure (roads, railways, lifelines, etc.) at risk are available in GIS form (Guzzetti, 2002).











What could we do for CKNP territory?

The IFFI italian project

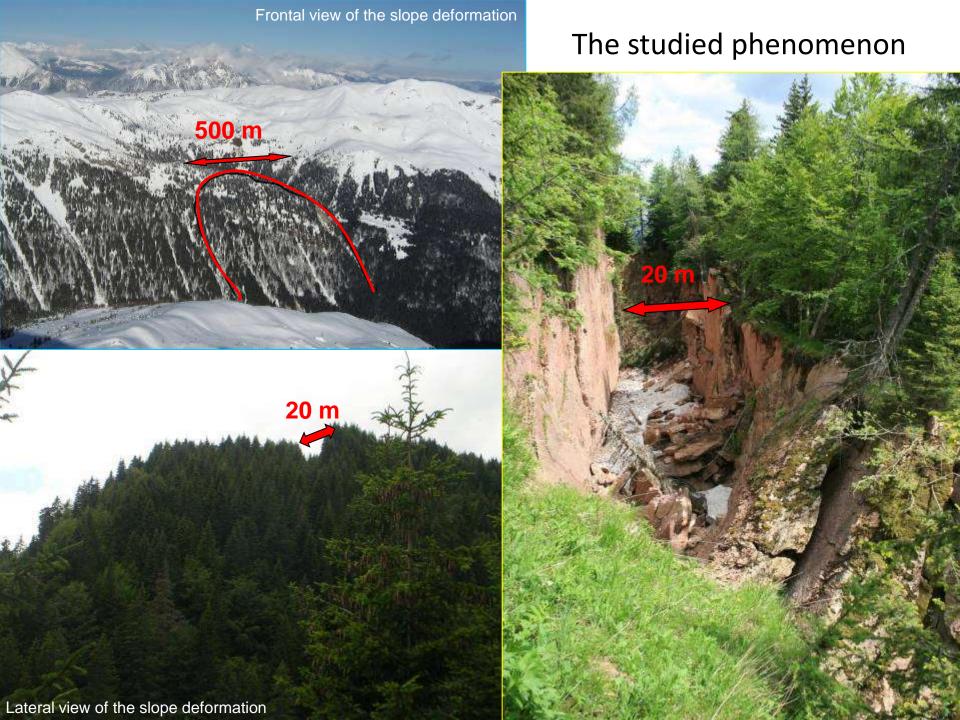
Italian landslide inventory

















The **Khaltaro** landslide is a sliding movement of detritical material over a rocky dipping surface. The length of the crown is approximately 200m, the height of the main scarp is about 4 m (**A** and **B**), all around the crown there are tension cracks 1,5m wide. Walking on the main body (**C**), it is possible to identify several longitudinal tension cracks with a gap of 10 to 15cm. This landslide is particular because there is a village with houses and fields at the toe of the slope, on the right side of the river. The phenomenon is moving towards the settlement. Witnesses reported that the movement began in 2009. Now the Pakistani government put up some tents (red circle) in a safer place (**C**), close to the village in order to avoid a possible disaster; **C**: Researchers on the main body of the landslide. On the background the blue tents belonging to the Civil Defence.











Landslide recognition



Landslide outline



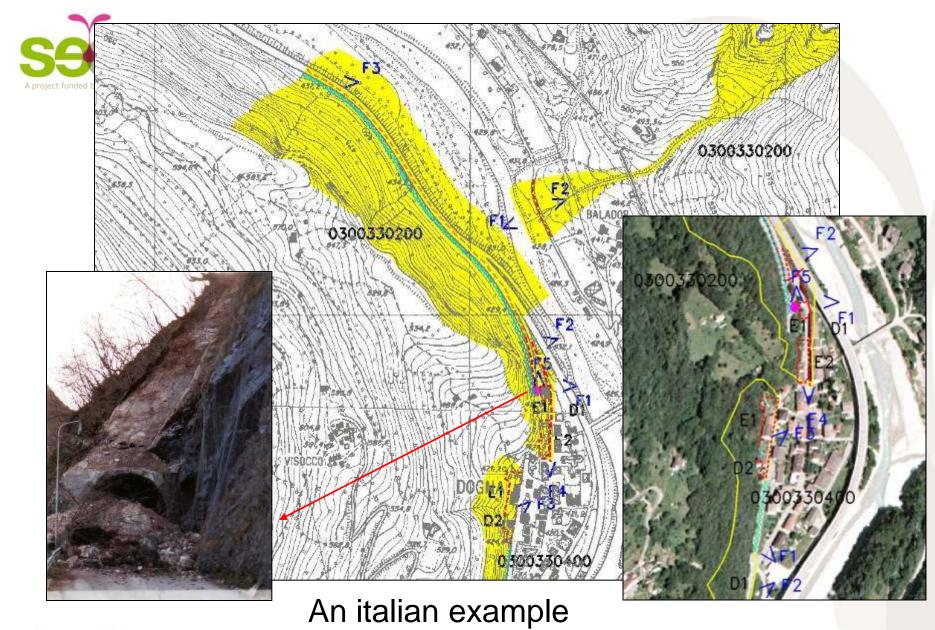
Landslide map













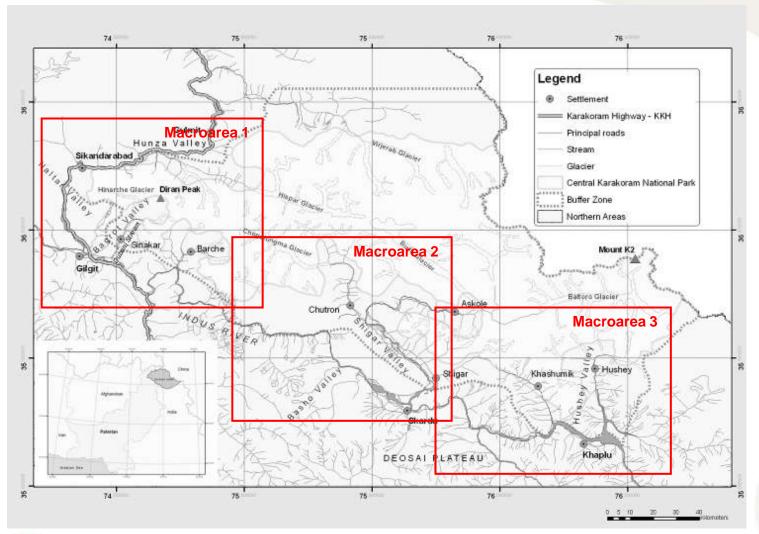








AREAS OF INTEREST







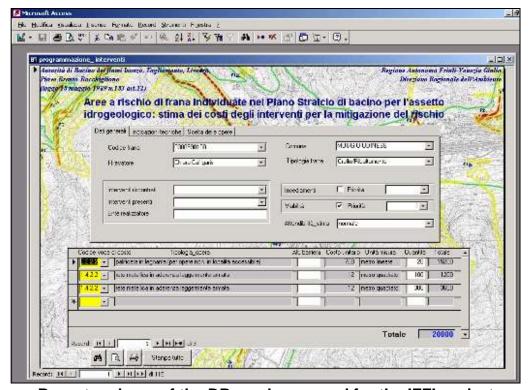






Methodological Approach

At present, after the surveys realized in 2011 and 2012, more than 100 landslides were recognized in the CKNP. For every landslide a report was made concerning all the morphological, geological and geotechnical available parameters. These information were added in a database similar to the one available for the italian IFFI project.



Report and one of the DB mask prepared for the IFFI project.









PROSETTO E			ter County or Barrie olde Deut	Payment Machinest	Course of Person	HEIDA DE CEMERATIO DES PRINCIPIES PRANCISES NOTA 2 2 4 Para N. Barrios G. Gassay S. Chant Y. Cristova R. T. Stravett, Ray S. Gazan F. Lastine C. Mortine R. S. Homeson R. Adella B. Vistova R. S. Gazan R. Lastine C. Mortine R. S. Homeson R. Adella B. Vistova R. Resistant R. Stravett R. S. Stravett R. St							
Sigla		OF	ene	III			0 0		ALTERNATION AND ADDRESS OF THE PARTY OF THE				
					GENE	DAILIN							
	нтріноюти		-	-			Locati	HINDROS		_	_		
Data Register Compilatore Committee													
-					otto Ad. dit	sone turni	series.	agramento.	Liverin, Pine	Brei	te-Bac	chigherie	
	ringene		Topon	MRQ 101					11/1				
CTR	Braile	15000	SETROA FRO	100 M	Lettere.	_		Toponimo	NE FRANA SIL	N WES	SANT		
list period			ni peviecali	water and the same			- 74	state	(Ingree				
Guota contre (ni) Genta unglisa (m)			Aglerati reconservito et (*) Ayea Setare (t.) (*)			- 6		No. of Assessment		9			
Curight erics. (_ 6n6			Volume finale trianta Spoolara V. (m²)			0		. Stanskill doller			9		
Destroito il proj Pendenco 3 (*)			Crofund to	W. EL (99)			Name and Advances			9			
STATE OF THE PARTY.			To be a second		000	LOSIA							
QHAR 1				-10	MED 2	TROVE OF			O rece culturals for				
Descrizione 1	fig.			-	entritione 2				50 men				
Discontinuità	F manual Co	Sect 19	Discorito	***	monara declara	11.0 44	with 6	scooling 14	33 ben	08082	D. COM N.		
D-SCORESSON,		-	Discordaudă 2: mews incinu			1 2 Assette discontinuità 90 etuent			22 matts	M0.	net a	tte.	
1 2 - Bind	Bers	-	1 Libotermina			OG regginger OG herengen synnesse			O right, with free petter O is not officers brothe point O is not officers brothe benche				
GG nasona GG strational			00 con 00 con types			GO travery orticitists GO travery physicilists			CPUP recommission production				
3/2 mole		- 8	DO women	esse.		QO Fas	enggin.	gewico	CO receipt intraster besting				
32 teautre 30 teautre			30 sea poeter			OO have - industryendo OO have - entrato pendo OO have industryendo 7 Degradaçõese		CO recon reterrollate CO reco general artificite, saline CO recon sectionature alique CO response al a loreca					
GO scaling D			GG was plantiles adherente										
OO selection 1.00			DIO temp granulare scrotta DIO temp connects			1907.796	120 hyein OO leggers opposits		23 and 23 and 23 and per green				
			OO have one	terra cosenna poco contratt. GGG or			OWN DRG	recircle.	1,909,9000	JE2Y.3	MICHAEL		
DO argantition - 2rd			GG term oig	2G teru oigance 2G units constance			QQ inchi degrada QQ simbilitan, degrada		G 3 seren prev. Index g y seren prev. algebre g 3 seren deropeten				
QO 994 (Stor	+ 60cmt		GO ordered	werler.	electories :	On microsophia	and apple	ngury i dati di	22 mm	CHHOIC .	prim)		
GO John Ma	-tim		COLUMN TO STATE OF STREET		William III	ARTHUR ME		Total State of	SUCCESSION FOR	DEL 3	ERBA	NTE	
O area otherses	C selfue spe	priverate redicate	2 frames	Mintackins Mark	Talantin Orbit	Mile March Mile March Mile Chr	origine .	G Mag	3.666	9.8	iw	⇒ Men	
0806	DUDOLA		of Boston of	111	EAS	HOMEN	COL	WHAT PAR	BARCISO	12.5	ilian.	COLUMN TO SERVICE	
Acque s	sperfit Wi	170	9 2		mento	9.66	10.2	Webselth	Valming	(4)	1.7	Malariale eco	
D segret		-0	O O mile O O statement			QQ with weight			PSE 1998	out.	00	NAME OF TAXABLE PARTY.	
C necessaries office:			O O strongert change			00 ava (+ 540*) 00 manus + 51			eni QO'ten			ers	
III ruscellements concentrate			G G sovepopt treating				O'Chape o Per						
Owners Owners 0.5			G G stierre het			- 3	OG reds reputs (4)			S AVAIL CO G STREET			
Q bostonia	O trustos O trustos	. 3		monte 'symte' descoratio			30.	-	emandamic O		20	C) begrate O wate legals	
8'	Prof (n)	0	440	delvier		Note sulla classifia			West				
-	m d T Anda	9	30		a cellifolione	Att-	1						
appropriation	material at Fig.	13	- 6	1. Triath	a sectorizaria a turn aperica	en.	1						
SALES OF SALES	an digitir a swite	1.0	-	e organic	a term asperfyze	Office.							
Today	Stee	10 We	O no dom	C public	O contacts	Devision	201		o seque	80	Dia .		
O GROWN	O gamen to	0.88	Science de	- Jense	O squifteen O towares	0 Gen	cuerty.	10	Coppesses	G mut	1000		
U-scopted		Gree	Leaharte	100	G multidrami	rate Gen	Andreaste Brade	UTRIPE BALL	Consequente	7,000	-		
	WIR WINGIN P		Special Contraction	ST INCH		Musele ST	inforte o	do ser					
MENSMERTO	CHE THE THE TOTAL	m dil	D Inventoria	4000		Numbers 649	make to	In DOUBLE	12.70				
	PERMITAL.		 avgress 	(Ofel	N. Comment	Population for	grana			-		OTTA!	
DATA DELL	n Dresi HY ng Ko Sé Higisan A	Mil-CLD-1	FARD DEATH	er Hall De Herror	EFFESO D				HATE				
	DECINE PROLE	199909				Sec.		SATISTICS					
Directors, france Directors pall outen Directors, object create Directors sorgers			18	glenel	Chevages	Fronte Dieta Cire vagini bilantimote Deta		erte merte	100		7900		
C celli localizzati O venerparas serja			orperii Djulitinates		D donor was stored						100		
		C représent D exempers ont d'enjue C controperdents D vertez parlets sorgent					characteristic Pleas econocranistics Germa						
@ riginflament	m Ow	PRE 201		[10	more art	Disensor	analogie	Giorni					



Field survey

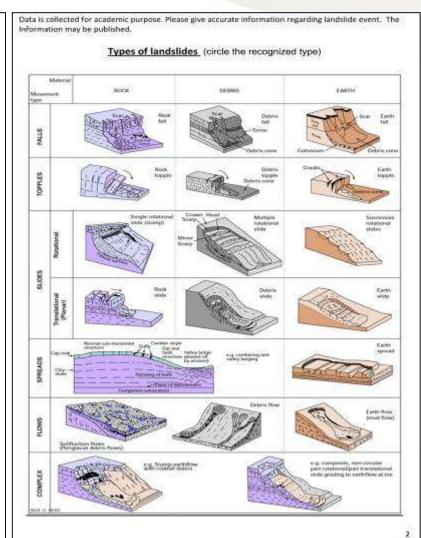






Landelides Identification Form

Date:	No:
Surveyor: (Name, Surnan	ne, Organization)
Village/Area/Valley:	
Position - using coordinate	system WGS 84 - UTM 43 N
(I.E.: 36°25'58"N 74°35'2	8°E; or killometric coordinates).
Coord X:	Coord Y:
Z (m a.s.l.):	
Landslide is: Active, react	tivated, quiescent, old landslide
Vegetation cover: bare so	oil, meadow, shrub, closed forest
Land use: cultivated area	s, wood, uncultivated, artificial surfaces (built areas, roads)
pasture	
Infrastructures Involved: r	road, house, bridge, track
Previous events, damage	s, people involved
Notes:	















Landslides
represent
a constant danger
along the roads
accessing to the
CKNP from every
direction.
On the right an
example in the
Bagrot Valley.
In red the active fan.













"Fresh" landslide on the way to Khaltaro. Repeated rock falls created a wide and heterogeneous deposit. The grain size is variable. The return time of the event is several times a year. Red arrow indicates the movement direction over a slope angle of about 45°.

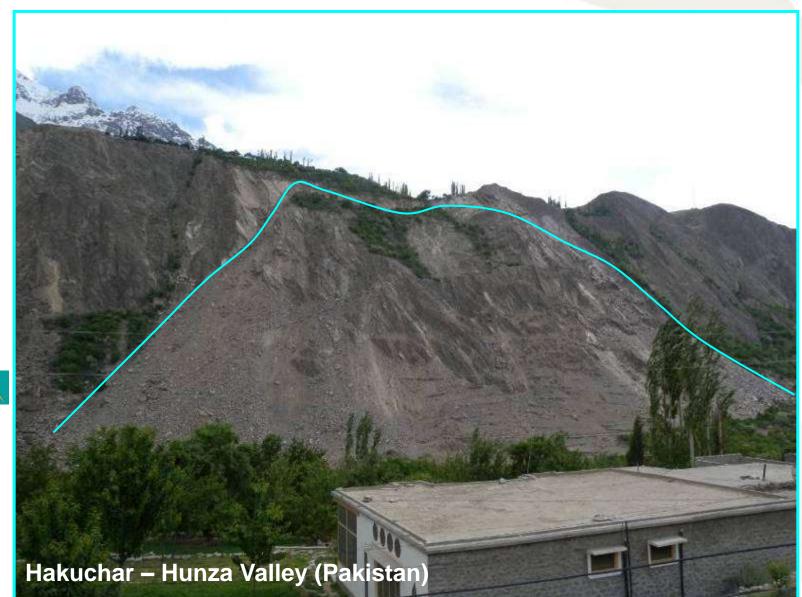






















On the way to Hopar glacier: the old road realized in a dangerous place. Fluvial banks erosion is one of the main triggering factors of the landslides in these narrow valleys.



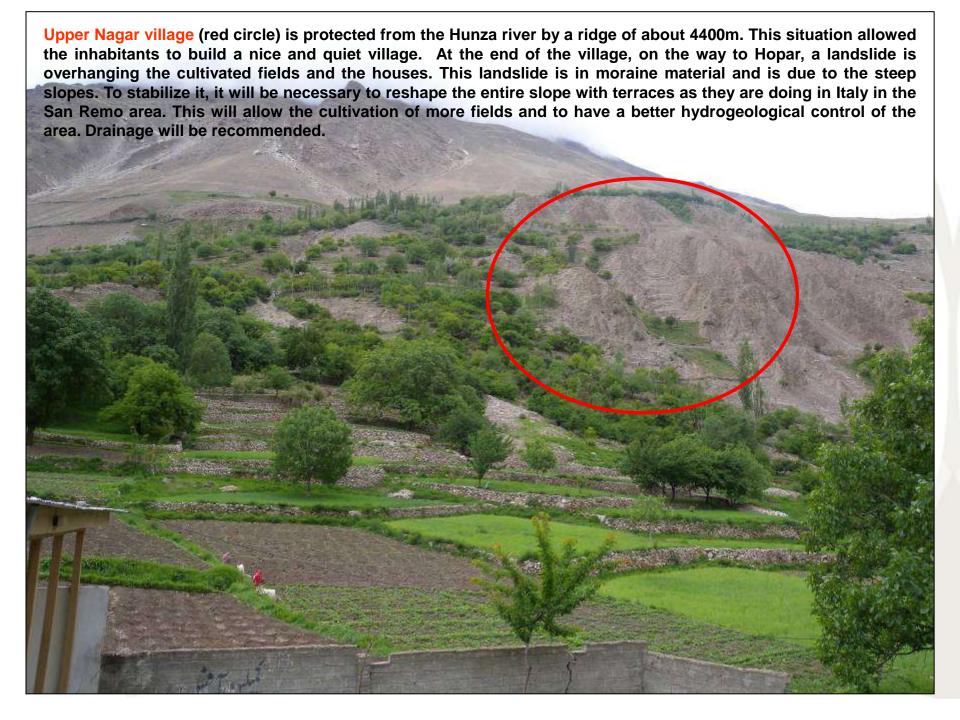








Outlined by a red line, the available detritical material, red arrows indicate the sliding direction. In pale blue the fluvial erosion.









Terraces banks are one of the most instable slopes due to their steepness and the nature of the involved loose or poorly cemented material.

Scarps are always affected by landslides all over the year but especially during the monsoon seasons

















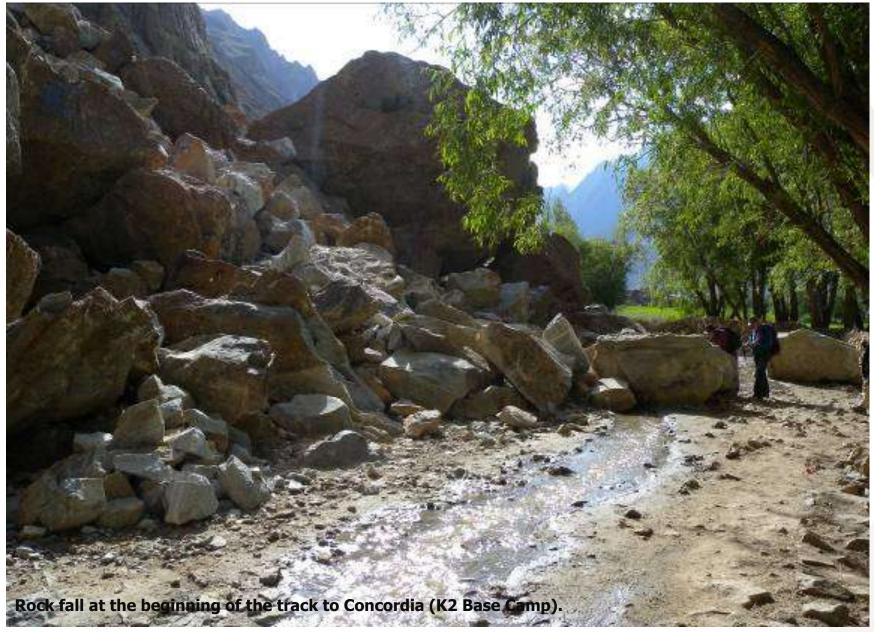






















Methodological Approach

Landslide identification













Landslide prone areas definition











Landslide susceptibility map through the GIS tool

Overlay of different themes: Geology Tectonic lines (faults, trusts..) Slope Aspect Curvature Land cover Land use



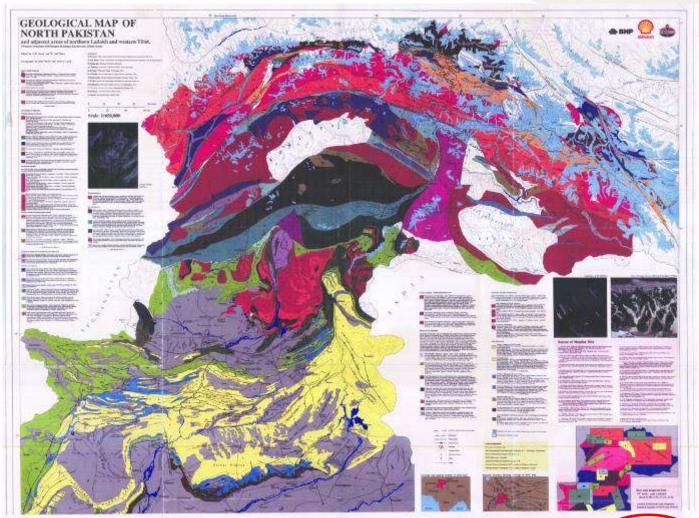








In Italy the working scale is 1:5.000



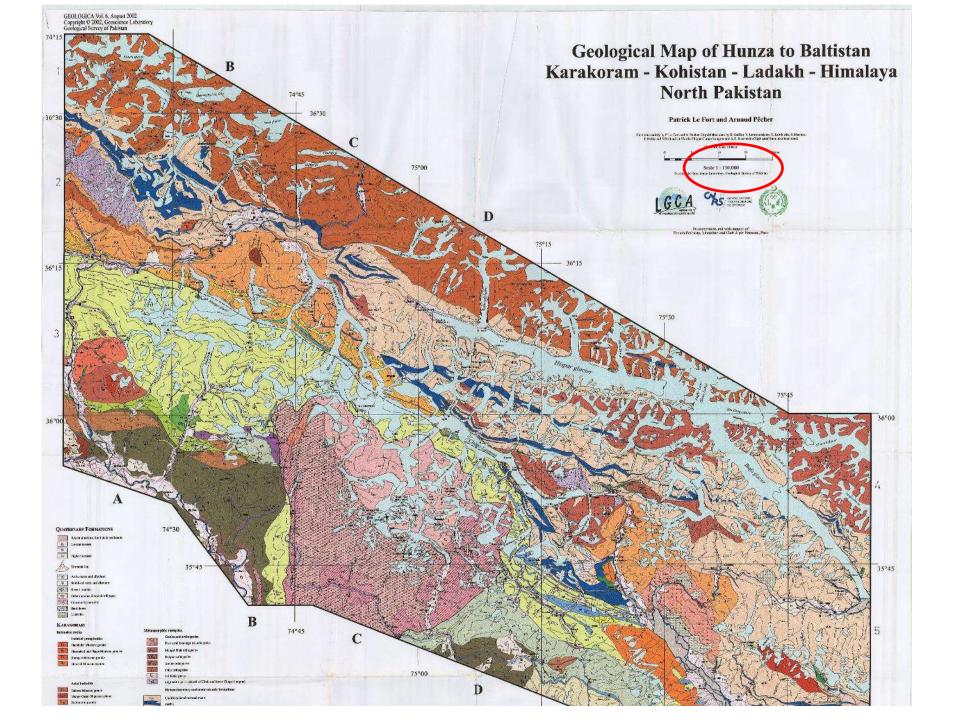






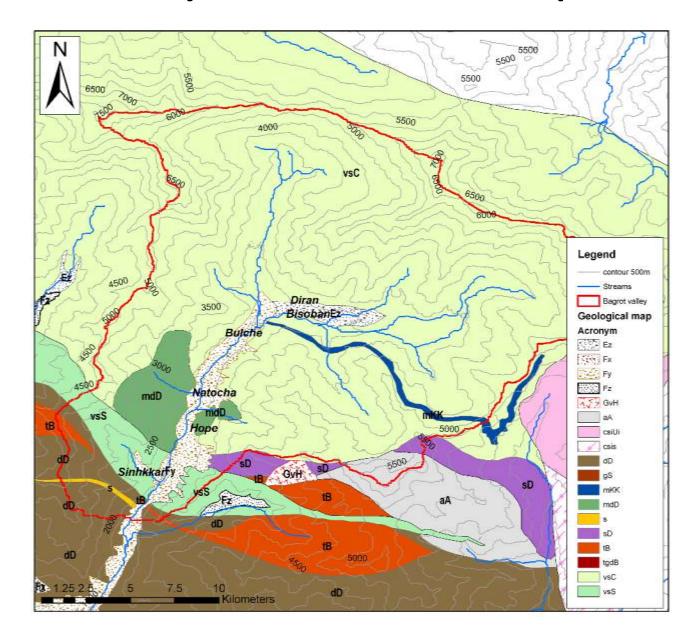
TO THE DESIGNATION OF THE PERSON

Searle and Asif, 1996-M.P. Searle, Khan Asif (Eds.), Geological map of North Pakistan 1: 650,000, lackwell, Oxford (1996)



The Bagrot valley area: an example

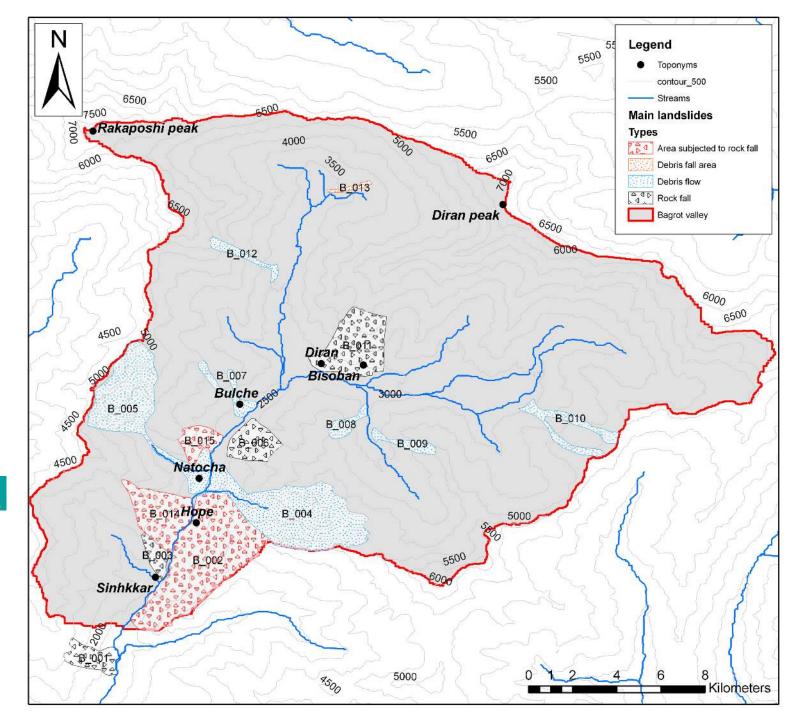






















SLOPE ASPECT CURVATURE

all derived from DEM and its relative accuracy











In a risk assesment analysis are considered also themes as ice and land cover

these data were provided by the SEED partners











According to AHP
(Analitycal Hyerarchy
Process) technique
and PAIR-WISE
comparison matrix

Factors and classes with the assigned relative ranks ranging from 1 to 9 in order of importance. Weights (0-9) were assigned to the classes: higher values indicate more influence towards landslide occurrence.

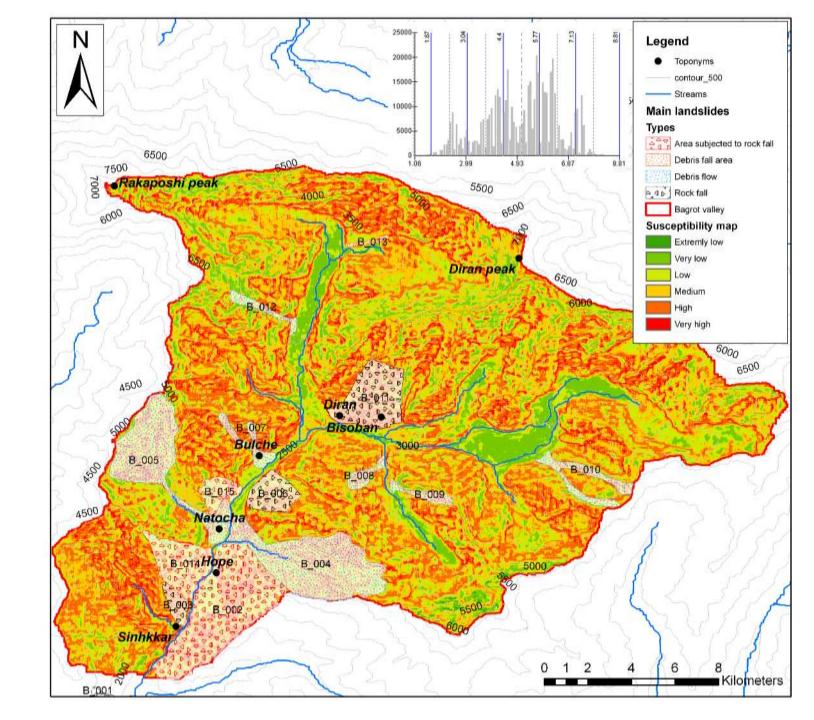
Factors	Classes	Ranks	Weights
Geology	Paragneisses (SKm)	1	4
	Andesite (Cv)		6
	Slates (Gm)		9
	Gabbrodiorite (KB)		6
	Permanent snow/ice		1
	cover		
Fault	0-250 m	1	9
buffer			
	250-500m		6
	500-750m		3
	> 750		0
Slope	0° - 15°	2	1
	15° - 25°		3
	25° - 35°		5
	35° - 45°		7
	> 45°		9
Aspect	Flat	1	0
	North		1
	Northeast		4
	East		7
	Southeast		8
	South		9
	Southwest		6
	West		3
	Northwest		2





















Risk Assesment

Landslide risk evaluation aims to determine the "expected degree of loss due to a landslide (specific risk) and the expected number of live lost, people injured, damage to property and disruption of economic activity (total risk)" (Varnes et al., 1984; Guzzetti, 2002).

To define the risk is necessary to identify which are the element at risk. In the CKNP case, they are mainly represented by the tracks taking tourists to the peaks.

So the researchers' attention is focused on these frequented areas.

Jointed data will form the basic risk map on which decision makers could start to work.











Results

- Three valleys were surveyed in 2011, 2 in 2012: Bagrot, Haramosh, Hopar, Chogolungma and Biafo and more than 100 main landslides were identified
- Data concerning lithological characteristics, land cover, tectonics, land use and glacier extension were collected
- The identified landslides were catalogued, and the main characteristics were defined
- A simple but complete landslide identification form was created and field tested
- A GeoDataBase was implemented
- A preliminary GIS investigation was realized
- Jointly with the GIS group, preliminary geological and tectonic maps of the CKNP area were prepared starting from a 1:650.000 and 1:150.000 scale studies
- A susceptibility map was produced









